NASA SBIR 2012 Phase I Solicitation

H6   Autonomous and Robotic Systems

NASA invests in the development of autonomous systems, advanced avionics, and robotics technology capabilities for the purpose of enabling complex missions and technology demonstrations supporting the Human Exploration and Operations Mission Directorate (HEOMD). The software, avionics, and robotics elements requested within this topic are critical to enhancing human spaceflight system functionality. These elements increase autonomy and system reliability; reduce system vulnerability to extreme radiation and thermal environments; and support human exploration missions with robotic assistants, precursors and caretaker robots. As key and enabling technology areas, autonomous systems, avionics and robotics are applicable to broad areas of technology use, including heavy lift launch vehicle technologies, robotic precursor platforms, utilization of the International Space Station, and spacecraft technology demonstrations performed to enable long duration space missions. All of these flight applications will require unique advances in software, robotic technologies and avionics. The exploration of space requires the best of the nation's technical community to provide the technologies, engineering, and systems to enable human exploration beyond LEO, to visit asteroids and the Moon, and to extend our reach to Mars.

Subtopics

H6.01 Spacecraft Autonomy and Space Mission Automation

Lead Center: ARC

Participating Center(s): JPL

Future human spaceflight missions will place crews at large distances and light-time delays from Earth, requiring novel capabilities for crews and ground to manage spacecraft consumables such as power, water, propellant and life support systems to prevent Loss of Mission (LOM) or Loss of Crew (LOC). This capability is necessary to handle events such as leaks or failures leading to unexpected expenditure of consumables coupled with lack of communications. If crews in the spacecraft must manage, plan and operate much of the mission themselves, NASA must migrate operations functionality from the flight control room to the vehicle for use by the crew. Migrating flight controller tools and procedures to the crew on-board the spacecraft would, even if technically possible, overburden the crew. Enabling these same monitoring, tracking, and management capabilities on-board the spacecraft for a small crew to use will require significant automation and decision support software. Required capabilities to enable future human spaceflight to distant destinations include:

- Enable on-board crew management of vehicle consumables that are currently flight controller responsibilities.

- Increase the onboard capability to detect and respond to unexpected consumables-management related events and faults without dependence on ground.

- Reduce up-front and recurring software costs to produce flight-critical software.

- Provide more efficient and cost effective ground based operations through automation of consumables management processes, and up-front and recurring mission operations software costs.

The same capabilities for enabling human spaceflight missions are directly applicable to efforts to automate the operation of unmanned aircraft flying in the National Airspace (NAS) and robotic planetary explorers.

Mission Operations Automation:

- Peer-to-peer mission operations planning.

- Mixed initiative planning systems.

- Elicitation of mission planning constraints and preferences.

- Planning system software integration.

Space Vehicle Automation:

- Autonomous rendezvous and docking software.

- Integrated discrete and continuous control software.

- Long-duration high-reliability autonomous system.

- Power aware computing.

Spacecraft Systems Automation:

- Multi-agent autonomous systems for mapping.

- Safe proximity operations (including astronauts).

- Uncertainty management for proximity ops, movement, etc.

Emphasis of proposed efforts:

- Software proposals only, but emphasize hardware and operating systems the proposed software will run on (e.g., processors, sensors).

- In-space or Terrestrial applications (e.g., UAV mission management) are acceptable.

- Proposals must demonstrate mission operations cost reduction by use of standards, open source software, staff reduction, and/or decrease of software integration costs.

- Proposals must demonstrate autonomy software cost reduction by use of standards, demonstration of capability especially on long-duration missions, system integration, and/or use of open source software.

Technology Readiness Levels (TRL) of 4 to 6 or higher are sought.

Potential NASA Customers include:

- Autonomous Mission Operations Project (http://www.nasa.gov/directorates/heo/aes/index.html)

- Habitation Systems Project.

  - (http://www.nasa.gov/exploration/analogs/hdu_project.html)

- Mission Operations Directorate

- Human Exploration Telerobotics Project

  - (http://www.nasa.gov/mission_pages/tdm/telerobotics/telerobotics_overview.html)

H6.02 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors

Lead Center: MSFC

Participating Center(s): GSFC, JPL

Exploration flight projects, robotic precursors, and technology demonstrators that are designed to operate beyond low-Earth orbit require avionic systems, components, and controllers that are capable of enduring the extreme temperature and radiation environments of deep space, the lunar surface, and eventually the Martian surface. Spacecraft vehicle electronics will be required to operate across a wide temperature range and must be capable of enduring frequent (and often rapid) thermal-cycling. Packaging for these electronics must be able to accommodate the mechanical stress and fatigue associated with the thermal cycling.

Spacecraft vehicle electronics must be radiation hardened for the target environment. They must be capable of operating through a minimum total ionizing dose (TID) of 300 krads (Si), provide fewer Single Event Upsets (SEUs) than 10-10 to 10-11 errors/bit-day, and provide single event latchup (SEL) immunity at linear energy transfer (LET) levels of 100 MeV cm^2/mg (Si) or more. All three characteristics for radiation hardened electronics of TID, SEU and SEL are needed.

Electronics hardened for thermal cycling and extreme temperature ranges should perform beyond the standard

military specification range of -55 °C to 125 °C, running as low as -230 °C or as high as 350 °C.

Using the target environment performance parameters for thermal and radiation extremes, proposals are sought in the following specific areas:

- Low power, high efficiency, radiation-hardened processor technologies.

- Technologies and techniques for environmentally hardened Field Programmable Gate Array (FPGA).

- Innovative radiation-hardened volatile and nonvolatile memory technologies.

- Tightly-integrated electronic sensor and actuator modules that include power, command and control, and processing.

- Radiation-hardened analog application specific integrated circuits (ASICs) for spacecraft power management and other applications.

- Radiation-hardened DC-to-DC converters and point-of-load power distribution circuits.

- Computer Aided Design (CAD) tools for predicting the electrical performance, reliability, and life cycle for low-temperature and wide-temperature electronic systems and components.

- Physics-based device models valid at temperature ranging from -230 °C to +130 °C to enable design, verification and fabrication of custom mixed-signal and analog circuits.

- Circuit design and layout methodologies/techniques that facilitate radiation hardness and low-temperature (-230 °C) analog and mixed-signal circuit performance.

- Packaging capable of surviving numerous thermal cycles, tolerant of the extreme temperatures, and the ionizing radiation environment on the Moon and Mars. This includes the use of appropriate materials including substrates, die-attach, encapsulants, thermal compounds, etc.

Technology Readiness Levels (TRL) of 3 to 5 or higher are sought.

Potential NASA Customers include:

- Autonomous Landing Systems.

- Mars Science Lab Instrumentation.

- Tele-robotics.

- Surface Mobility.

- Nuclear Systems.

- Robotic Satellite Servicing.

- In-Space propulsion.

- Deep Space X-Ray Navigation and Communication.

- Deep Space Optical Communications.

- Mars Sample Return.

- Europa Orbiter.

- Near Earth Objects and Primitive Body Missions.

- Space Launch System.

- Extra-Vehicular Activity Suits

H6.03 Human-Robotic Systems - Manipulation Subsystem

Lead Center: JSC

Participating Center(s): ARC, JPL

This call for technology development is in direct support of the Human Exploration and Operations Mission Directorate (HEOMD). The purpose of this research is to develop component and subsystem level technologies to support robotic precursor exploration missions. To that end, it is the intent of this Subtopic to capitalize on advanced technologies that allow humans and robots to interact seamlessly and significantly increase their efficiency and productivity in space. The objective is to produce new technologies that will reduce the total mass-volume-power of equipment and materials required to support both short and long duration planetary missions. The proposals must focus on component and subsystem level technologies in order to maximize the return from current SBIR funding levels and timelines. Doing so increases the likelihood of successfully producing a technology that can be readily infused into existing robotic system designs. This research focuses on technology development for the critical functions that will ultimately enable surface exploration for the advancement of scientific research. Surface exploration begins with short duration missions to establish a foundation, which leads to extensible functional capabilities. Successive buildup missions establish a continuous operational platform from which to conduct scientific research while on the planetary surface. Reducing risk and ensuring mission success depends on the coordinated interaction of many functional surface systems including power, communications infrastructure, mobility, and ground operations. This Subtopic addresses robotic manipulation and related technology needs associated with planetary surface systems infrastructure, interaction of humans and machines, mobility systems, payload and resource handling, and mitigation of environmental contaminations.

The objective of this Subtopic is to create human-robotic technologies (hardware and software) to improve the exploration of space.

Robots can perform tasks to assist and off-load work from astronauts. Robots may perform this work before, in support of, or after humans.

Ground controllers and astronauts will remotely operate robots using a range of control modes (teleoperation to supervised autonomy), over multiple spatial ranges (shared-space, line-of-sight, in orbit, and interplanetary), and with a range of time-delay and communications bandwidth.

Proposals are sought that address the following technology needs:

- Subsystems that improve handling and maintenance of payloads and assets.

- Enable crew and ground controllers to better operate, monitor, and supervise robots.

- Improve the transport of crew, instruments, and payloads on planetary surfaces, asteroids, as well as in space.

This includes:

- Robot user interfaces.

- Automated performance monitoring.

- Tactical planning software.

- Ground data system tools.

- Command planning and sequencing.

- Real-time visualization/notification.

- Software for situational awareness, as well as, subsystems to improve handling and maintenance of payloads and assets.

- Tactile sensors.

- Human-safe actuation.

- Active structure.

- Dexterous grasping.

- Modular "plug and play" mechanisms for deployment and setup.

- Standardized interfaces for structural loads & commodity transfer.

- Novel robotic manipulation methods.

- Small/lightweight devices to provide subsurface access and sampling.

- Small/lightweight regolith excavation, handling & delivery devices.

- Regolith anchoring methods for near Earth objects (neo).

- Subsystems to improve the transport of crew, instruments, and payloads on planetary surfaces, asteroids, and in-space.

- Hazard detection sensors/perception.

- Active suspension.

- Grappling/anchoring.

- Legged locomotion.

- Sub-surface locomotion.

- Robot navigation.

- Infrastructure-free localization.

Technology Readiness Levels (TRL) of 2 to 6 are sought.

Potential NASA Customers include:

- Software Robotics and Simulation Division (JSC-ER).

- International Space Station.

- Habitat Development Unit (AES Project).

- Multi-Mission Space Exploration Vehicle (MMSEV-AES Project).

- MPCV Orion Project.

- R2 (Robonaut Project).